CIHM
Microfiche
Series
(Monographs)

ICMH
Collection de
microfiches
(monographies)

Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques

BULLETIN NO. 240] [JUNE, 1916

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE

Some Bacterial Diseases of Vegetables Found in Ontario

DAN. H. JONES.

During the last fifteen or twenty years it has been found that some very destructive diseases of plants are caused by certain species of bacteria. As we are frequently getting inquiries regarding some of these diseases, and the methods for controlling them, we have thought it advisable to prepare this bulletin for distribution to those interested.

Bacteria are microscopic plants that to be seen have to be very highly magnified. On an average they are about 1/5,000 of an inch long and 1/15,000 of an inch thick. Of all living organisms that are known they are the smallest and most simple in structure. Under favorable conditions they multiply very rapidly. One bacterium can multiply to ten millions or more in twenty-four hours. Their method of reproduction is simply to absorb food and divide in the middle. This dividing takes place about every twenty minutes or half an hour under suitable conditions of food supply and temperature. They are found in large numbers wherever other forms of life—man, animal or plant—exist. An ounce of good garden or field soil contains many millions of them, many species being represented in this number. Most species are very beneficial, in fact plants could not grow without them in the soil. A few, however, are injurious. Of these latter, some cause disease in man and animals, such as tuberculosis, typhoid, etc., and others cause various diseases of plants.

TYPES OF BACTERIAL DISEASES OF PLANTS.

The bacterial diseases of plants fall naturally, according to the changes which they induce in the host plant, into four types as follows: 1, Bacterial Soft Rots; 2, Bacterial Wilts; 3, Bacterial Canker or Blights; 4, Bacterial Galls.

BACTERIAL SOFT ROT OF VEGETABLES.

Bacterial soft rot is a disease liable to attack fleshy vegetables and flowers, particularly carrots, cauliflower, turnips, celery, tomatoes, potatoes, German iris and calla lily, and in a lesser degree onions, asparagus, salsify, sugar beet, mangel, muskmelons, rutabaga, and some others. Occasionally the disease results in heavy losses to the grower of these crops.

GENERAL APPEARANCE OF THE DISEASE.

As the name signifies, the disease results in a soft, wet rot of the plant attacked. The rotted portion of the plant is darker in color than the rest of the plant. The color of the diseased part varies from a light, reddish brown to a very dark

brown in the case of white or creamy fleshed plants, such as cauliflower, turnips, or heart of celery, and a very dark green, almost black, in case of the green tissues which are attacked. The diseased tissue is very soft and mushy and frequently has a strong and offensive odor. There is a clear line of demarcation between the diseased and healthy tissues, the disease inducing complete destruction of the tissue as it advances from the point of inoculation.

The Cause of the Disease.

The cause of the disease is a bacillus which has been given a variety of names by different men, who at different times in various countries have studied the disease in different species of plants. Prof. L. R. Jones, of Vermont, studying the disease in a crop of carrots, named the causal organism *Bacillus carotovorus*. Prof. Harrison, of Ontario, studying the disease in an outbreak in a crop of cauliflower, named it *Bacillus oleraceae;* Prof. Potter, in England, studying the disease found it to be destructive to quite a number of varieties of plants and named it *Pseudomonas destructans*. N. J. Giddings, of Vermont, studying the disease in a crop of melons, named it *Bacillus melonis*; C. O. Townsend, of Washington, studying the disease in a greenhouse of calla lilies, named it *Bacillus aroideae*. More recent investigations have shown that the disease is practically one and the same in all the plants mentioned. While to the bacteriologist there may be a few slight differences in the nature of the bacillus causing the disease in the melon from that causing the disease in the lily, or that causing the disease in carrots, turnips and cauliflower and other vegetables, yet the disease is for all practical purposes to the horticulturist one and the same—a soft, wet rot of the plant attacked.

Histology of the Disease.

When the *soft rot bacillus* gets on to a freshly made wound, either small or large, in plants liable to the disease, it feeds on the plant juice which emerges on to the wounded surface, and on this it grows and rapidly multiplies. As it multiplies it produces digestive enzymes, *e.g.*, cytase, which digests cellulose; diastase, which digests starch; and proteolytic enzymes, which digest proteids. These are diffused through the living bacterial cells and act upon the vegetable tissue around them, making it soluble to be used as food material by the bacilli. The action of these enzymes is greatest on the middle lamellæ, *i.e.* the strip of tissue which lies between the walls of adjacent plant cells. The middle lamellæ are quickly dissolved and form good food for the multiplying bacilli, which, as they multiply, pass along between the cells, filling the intercellular spaces and separating the cells from one another. The protoplasm within the plant cells is plasmolised, that is, it is made to shrink from contact with the cell walls and to contract into an irregular mass within the cell, by the action of the enzymes produced by the bacilli in the intercellular spaces. In this way the collapse of the tissue is brought about, and such tissue constitutes the rotted part of the plant.

In *cauliflower* the disease is found more often in the flower than in the leaves or stem; the latter parts, however, are also subject to attack.

The disease in the flower is very easily noticed, the normal color of the flower being white or creamy and that of the diseased portion light to dark brown and very soft, and having an offensive odor. The writer has noticed a number of times dark brown areas varying in size which looked at first sight like soft rotted areas, but which on investigation proved to be discolorations due to excreta of

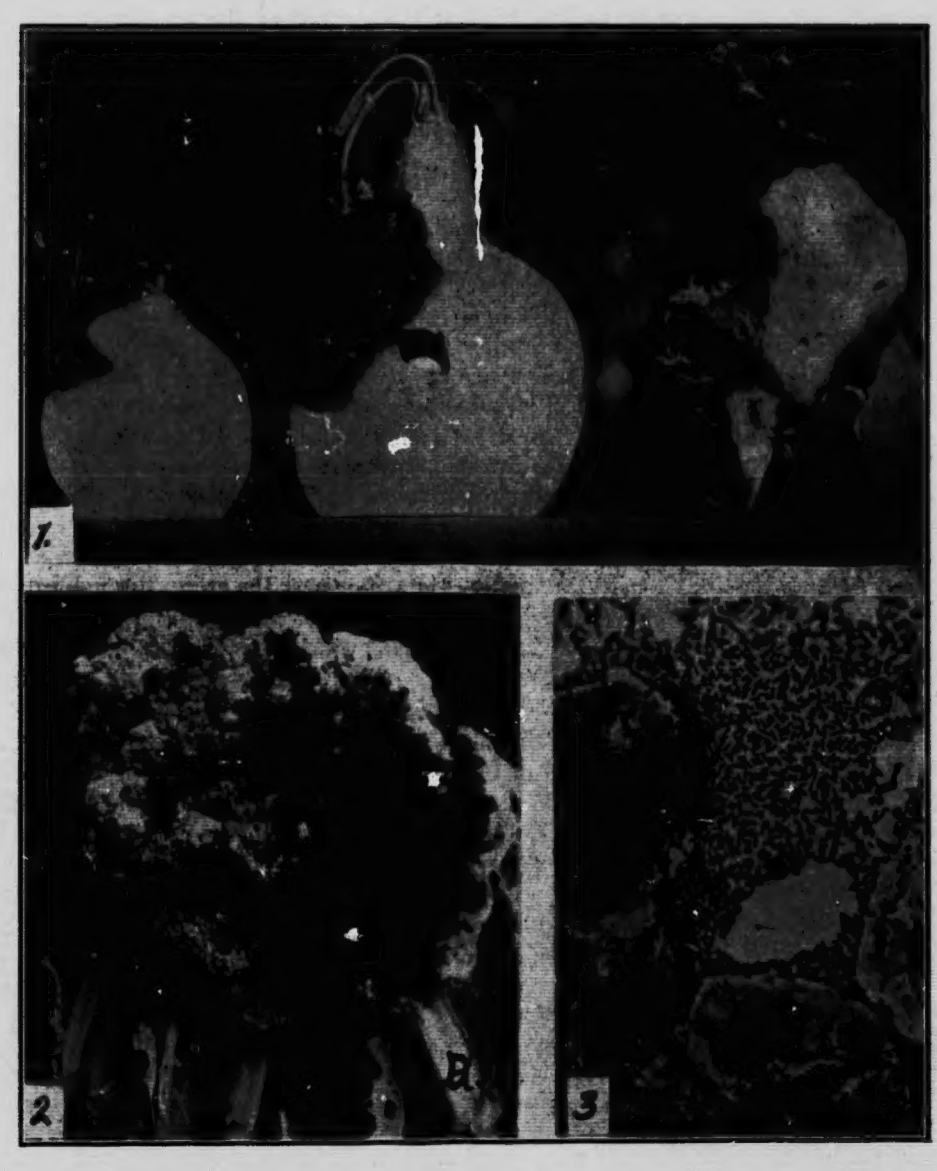

PLATE I.

Fig. 1. Bacterial soft rot of turnip. Specimens obtained from the field and cut through the middle. Each specimen had been accidentally inoculated with the hoe or cultivator near the crown.

Fig 2. Bacterial soft rot of cauliflower, natural infection; specimen taken from the garden.

Fig. 3. *B. carotovorus*, the vegetable soft rot bacillus seen between the cells of the broken-down rotting cauliflower tissue (x 1000 di.).

cabbage caterpillars which had been feeding on the leaves overhanging the flower. In such cases the tissue immediately below the surface of the discolored area is not softened as it is in the case of the rot, and the discoloration is only on the surface. Observations have shown, however, in a number of such cases that the rot has later developed within such discolored area, thus indicating that in all probability the caterpillar had previously been feeding on a rotted plant, and all the bacilli in the portion consumed had not been killed in the process of digestion, but had passed through the alimentary tract of the caterpillar with the excreta, or that the mouth parts and feet of the caterpillar had been contaminated from a diseased plant, and on crawling over the surface of the healthy plant had inoculated it.

In the stem the disease results in a complete softening of the interior, the softened tissue becoming a dirty gray in color with strong odor. The disease may enter the stem from injury to the exterior caused by the breaking of leaves, or the biting of insects, slugs and caterpillars during cultivation, etc., and from the stem pass up into the flower, or the stem may become so far rotted that the head will fall off. The stem may also become infected through the flower.

In the leaves the disease is more often found in the petiole or midrib rather than the blade. It appears as a dirty gray softened area, which, when in the petiole, soon results in collapse of the leaf.

In *turnip* the disease most frequently enters at or near the crown through caterpillar or slug attack, or through injuries received during hoeing or cultivation. It softens or rots the leaf petioles at their base, causing them to fall over, and spreads slowly in dry weather, rapidly in wet weather, through the tissue of the root, inducing a brown-colored soft rot with strong odor.

In *carrot* the disease enters and develops in much the same way as described for the turnip. It is more apt to spread rapidly through a crop that is thickly sown and not well thinned out, the shade produced by the heavy tops making ideal conditions by keeping the ground moist for the development of the disease when once it gains entrance, and harboring slugs and caterpillars that spread the disease. Carrots which crack beneath the ground are liable to be attacked by the disease, the soft rot bacillus gaining entrance to the tissue through the cracked surface.

In *celery* the disease is not very common, but when present is most often found starting at or near the tops of the young growth. The affected parts become dark brown and very soft and mushy. The parts so affected cease growing, the growing tips being destroyed, and the disease slowly passes down the stem, completely rotting the tissue as it progresses. If the disease starts below the end of the stem, the upper part soon topples over as a result of the softening of the part attacked. The disease spreads from plant to plant through the agency of slugs, caterpillars, etc., and during the process of handling when cultivating and banking up. When the plants are stored away for winter use, if a plant having the disease is stored with the healthy plants, the rot is liable to spread to the healthy specimens.

The bacterial soft rot is very common in tomatoes during wet seasons. It is found most frequently in the fruits that are in contact with the soil after they have commenced to ripen. The bacillus will not readily penetrate through the unbroken skin of the tomato. But when a tomato is resting on the damp earth, that part of the skin in contact with the soil is frequently weakened, thus providing a means of access to the bacillus. This, however, is not the only means whereby the disease enters the fruit. Slugs are very partial to tomatoes just ripening. In their attack on the fruit they eat through the skin, leaving the interior flesh ex-

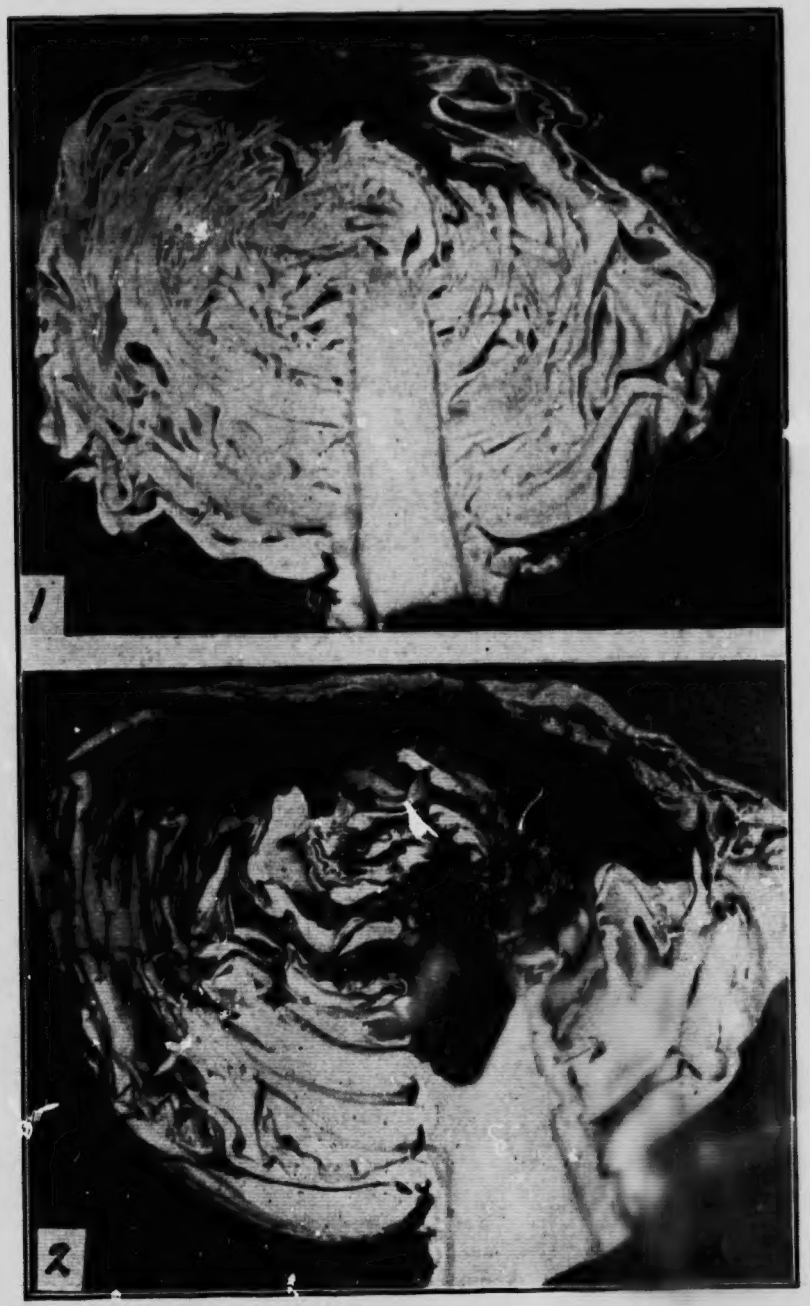

PLATE II.

Fig. 1. Bacterial soft rot of cabbage. Artificial stab inoculation of a pure culture of B. carotovorus in healthy cabbage. Seven days after inoculation.

Fig. 2. Same as Fig. 1, twenty days later.

posed. This exposed surface is an ideal medium for the bacillus of soft rot to develop in. The writer has found many tomatoes, particularly in wet seasons, when slugs are plentiful, that have contracted the disease in this way.

Eradication and Control of the Disease.

Spraying with fungicides, which is so effective in controlling the fungous diseases of plants, is of no avail with bacterial diseases, as the bacteria which cause the disease act in the interior tissue rather than on the surface; hence the spray will not reach them.

Spraying with insecticides is helpful indirectly, as it tends to keep in check the insects, slugs, caterpillars, etc., which are one of the most common means of spreading bacterial diseases from one plant to another.

As a rule the best method to adopt in dealing with a plant affected with bacterial disease is to carefully remove and burn it. Insects, garden tools, etc., coming in contact with it will spread the disease to the plants with which they come in contact later. This is particularly the case with the bacterial soft rot of plants, as the affected tissue is so very soft and pulpy that it cannot be touched without heavily contaminating whatever touches it.

Again, if affected plants are allowed to remain on the ground they infect the soil with the organisms of the disease to such an extent as frequently to cause the disease to establish itself in the succeeding crop of any plants which are susceptible to the disease, but particularly plants of the same species.

Some time ago we received for examination a box of rotting, half-developed turnips from a farmer, who said that five per cent of his crop were similarly affected. Upon enquiry we found that the affected ones were growing on soil on which turnips had been grown the year previous, and 25 to 30 per cent. of these having been affected with the same rot had been allowed to remain on the ground at harvest time, and later were plowed in. In was evident that the soft rot bacilli from the diseased turnips had remained alive in large numbers in the soil, and that many of the turnips of the subsequent crop had been inoculated with these bacteria during cultivation and possibly by insect attack also, see Pl. I., Fig. 1. The hoe or the teeth of the cultivator would get contaminated from the soil, and accidental wounding of a turnip with such an implement would result in the inoculation of the turnip with the germs of the disease.

Another man sent a head of celery for examination which we found to be suffering from the bacterial soft rot in the young growing tips. In reply to our enquiries he sent word as follows: "I had celery on this ground two years ago, and the row that was where the rot is worst now was so bad then that I lost all, but only that row was affected. This year two rows have it, but one a great deal worse than the other. There were five rows in this patch all planted about the same time. The healthy rows matured away ahead of the two which were diseased." Here it is evident that the soft rot bacteria had remained in the soil for two years, and that cultivation had spread the bacilli to some extent through the soil, as on the second occasion that celery was grown on that patch the plants in two rows developed the disease.

The writer had under observation a garden where turnips and carrots were both affected with the bacterial soft rot. The affected plants were not removed, but were dug in. The next year tomatoes were planted on the same ground. The disease did not develop in the growing plants, as care was taken not to wound them. However, about 60 per cent. of the fruit became affected before it was fully ripe.

PLATE III.

Bacterial Soft Rot of Celery.

Fig. 1. Artificial needle inoculation of pure culture of B. carotovorous (isolated from rotting cauliflower) into the young vigorous growth of celery. Five days after inoculation, kept at 25° C.

Fig. 2. Same as Fig. 1, five days later.

Fig. 3. Same as Fig. 1, ten days later.

Fig. 4. Same as Fig. 1, three weeks after inoculation, showing complete collapse of plant.

Fig. 5. B. caratovorus, the vegetable soft rot bacillus, between the cells of rotting celery tissue (x 1000 di.).

The affected specimens were either those that were in contact with the soil or had been bitten by slugs. The soft rot bacteria, which cannot penetrate through the sound skin of a tomato, found entrance through the slug bites or through the weakened skin that had been in contact with the soil.

Therefore, in order to prevent losses from bacterial soft rot of plants, remove and burn affected plants, or parts of plants, as soon as observed; be careful during cultivation not to wound plants, and keep caterpillars, slugs and biting insects in check. Affected plants should never be put on the compost heap or manure pile.

Harvesting and Storing.

When harvesting and storing turnips, cauliflower, cabbage, celery, tomatoes or other vegetables from crops in which the disease has been present, great care should be taken not to include any specimen that shows the slightest appearance of the disease, or to smear the healthy specimen with the soft rotted parts of diseased specimens. If these precautions are neglected, the disease is liable to establish itself and spread more or less rapidly through the entire crop stored.

Soft Rot of Potatoes.

The diseases to which potatoes are subject are numerous. Various species of fungi are responsible for most of them, but bacteria are involved in some cases. This is particularly so in the case of soft rot.

The soft rot is more prevalent in wet weather than in dry weather, and in low lying, undrained wet soils, than in high, dry or drained soils.

During the season of 1915 potato soft rot was prevalent in many districts of Ontario, and the writer devoted considerable time to observing and studying the rot throughout the season in the neighborhood of Guelph, and investigations are still in progress in this connection.

Black leg was found common in the early part of the season and this disease killed many young plants. Later in the season the soft rot developed and destroyed a large percentage of the tubers that had formed.

Similar bad outbreaks of the soft rot occurred at Guelph in 1904 and 1905, at which time Prof. F. C. Harrison of this Department made an extended study of the disease. Outbreaks of less severity and extent have occurred from time to time since.

The following is a partial quotation of Prof. Harrison's description of the disease as published in the Centralblatt für Bakteriologie, 2 Abte. Vol. 17, 1906-7.

General Appearance of the Disease in Growing Plants.

"In the majority of cases the first symptoms appear when plants are in full vigor of growth. A plant here and there will present a sickly appearance—drooping leaves, discolored yellowish. In a few days the stems gradually droop, finally rest on the ground and shrivel up.

When the leaves are turning yellow, black areas may be seen on the stems and petioles, and if these are cut through the fibro vascular bundles and adjacent tissues will be found brown or black according to the progress of the disease. The stems are usually most discolored near the ground. The leaves occasionally turn black without previous yellowing.

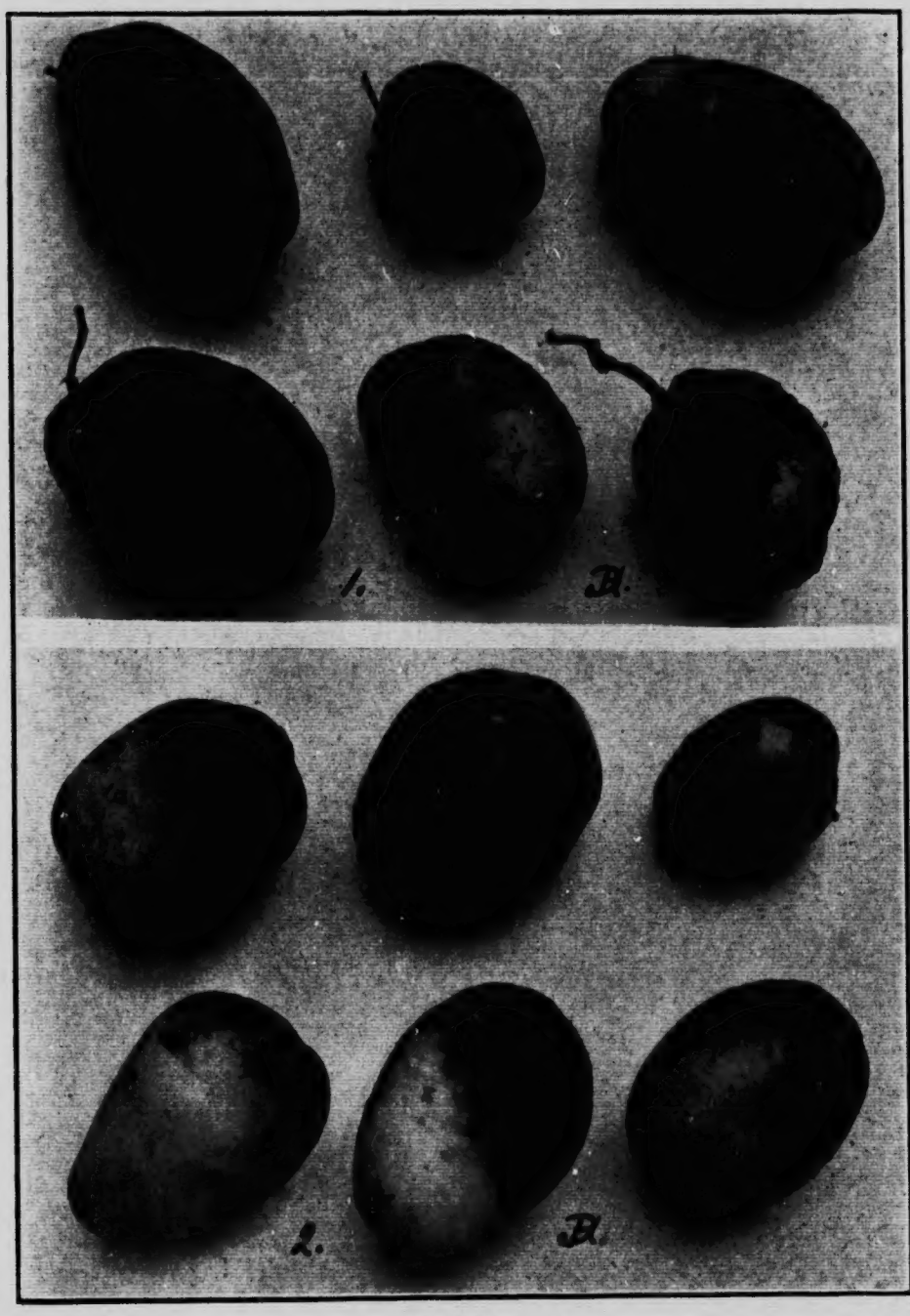

PLATE IV.

Potato tubers, showing bacterial soft rot in various stages of development, some tubers entirely rotted, others only partially affected.

Fig. 1. Six tubers that contracted the disease directly through the stem from the parent plant.

Fig. 2. Six tubers that contracted the disease at the eye end from coming in contact with other diseased tubers.

The tubers show the most characteristic indications of the disease. Even when the plant appears in a fairly thrifty state, the tubers may be badly diseased, out of all proportion to the apparent vigor of the plant. At first sight, most of the potatoes appear to be sound, but on closer examination the skin over certain areas may be found discolored a reddish brown, something like a bruise, with a firm consistency, but as the disease progresses, the flesh beneath the dark portion becomes soft. There is a sharp line of demarcation between the healthy and diseased portions, frequently marked by a black line, the darker color being toward the sound part of the potato and gradually shading to a lighter brown on the diseased portion.

On breaking the skin a white, turbid liquid which may contain gas bubbles can be pressed out. This liquid rapidly turns black on exposure to the air. The skin over the diseased area easily peals away and the exposed flesh is watery and white, but soon discolors in the air, becoming almost black. In later stages of the disease the flesh softens to a watery pulp and becomes highly offensive with a putrefactive odor. In the final stage the potato becomes a mass of black soft pulp.

Several modifications of these conditions may be noticed. Thus the discoloration and blackening may be confined to only one portion of the tuber, and at other times the whole of the tuber beneath the skin is softened and discolored with the center portions quite sound. In some cases the most rotten tuber was the seed potato, in others the new potatoes.

The rot seemed to extend from the one first infected to the rest, infection evidently caused by actual contact.

If the potatoes are allowed to dry out, the tissues between the healthy and already softened portions undergo a corky modification.

After the potatoes are dug, and the apparently sound ones are put into a cellar or pit, the disease continues to spread, and on cutting open affected potatoes they will be found with brown or blackened areas. Such areas are not confined to the fibro vascular ring, but may be of any size and in any portion of the potato.

Natural Method of Infection.

One of the principal means of infection is the diseased condition of the seed potato when planted. In a large number of plants examined in the field the seed potato was found to be badly rotted and the young potatoes around were infected on the side nearest the rotted tuber. While it is doubtful if the potato rot bacillus can penetrate the unbroken epidermis, yet, if a small amount of rotted potato is placed on the unbroken surface of a healthy tuber, it will in a short time cause infection. This is probably due to the large amount of cytase in the rotted mass, which is able to bring about a solvent action on the cement substance of the cells of the healthy potato.

In the event of the organism being in the soil, infection may take place through wounds made while cultivating."

Prof. Harrison isolated a bacillus from the affected tissues, which he named *Bacillus solanisaprus*. He found it present in the stems and tubers or other parts of the plant affected.

He states: "In the stems the bacteria first make their appearance in the vessels of the fibro vascular bundles and from thence invade the surrounding tissues dissolving the middle lamella causing disintegration of the cells and

PLATE V.

Tubers in advanced stages of the bacterial soft rot.

forming cavities. In the tuber the action of the bacteria is first on the lamella of the cells and in fresh made preparations of partially rotted tissues free cells are abundant, showing the dissolving action of the enzymes of the bacteria on the cement substance or pectase layer of the cells."

The writer found all the above symptoms common in the rotting potatoes during investigations in 1915. A bacillus was isolated from several diseased tubers which corresponded in almost every particular, morphological and cultural, with *B. solanisaprus*, as described by Prof. Harrison. This bacillus when inoculated into raw potato kept in a moist chamber, caused a soft wet slimy rot to develop rapidly, completely destroying the potato in a few days.

Other Causes of Soft Rot in Potatoes.

In addition to finding *B. solanisaprus* causing the soft rot in the potatoes examined in 1915, the writer found many specimens which were affected with a species of *Fusarium*, a fungus which produces a wilt of potato tops and a dry rot of the tubers affecting them both in the soil and in storage. This disease has been described by Dr. Erwin Smith. (See Bul. 55, Bureau of Plant Industry, U.S. Dept. of Agriculture, also Bul. 229, "Fusarium Blight and Dry Rot of Potato," by T. F. Manns, Ohio Agricultural Experimental Station.) Growing potatoes which are affected with this fungus in wet weather are apt to present an appearance strongly resembling that described above as being due to *B. solanisaprus*. The plant, weakened by the disease, becomes an easy prey to the ordinary decay bacteria of the soil and other fungi and the result on the tubers of the combined action of these various micro-organisms is a soft rot both of the plant and the tubers. If, however, the season is a dry one a wilt of the affected plant and a dry rot of the tubers is the result.

Control of the Disease.

1. Do not plant potatoes that show any brown discoloration or other indications of either wet or dry rot.
2. Plant in well drained land.
3. Destroy by burning all diseased plants and tubers.
4. On land where the disease has been prevalent, do not plant potatoes or tomatoes for several years as both *B. solanisaprus* and the *Fusarium* live in the soil a considerable time, how long has not been determined.
5. Plant those varieties of potatoes that have proven most resistant to the rot.
6. Spray with insecticides as Paris green, to keep down insects and with Bordeaux mixture to prevent both the so-called Early Blight and Late Blight from developing in the tops of the plants. The latter is liable to lead to a soft rot of the tubers somewhat similar to that which follows the *Fusarium* affection.

BLACK LEG OF POTATOES.

As the name of this disease implies, there is a darkening of the lower stems of affected plants. This discoloration may range from brown to black; usually it is dark brown. It is most often found below the soil surface from the seed tuber up, but may extend upwards an inch or two above the soil. The discolored part shrinks and is liable to rot.

PLATE VI.

Fig. 1. Young potato plants showing *Black Leg*. The three stems to the left killed; the two to the right badly affected. (Both Rhizoctonia mycelium and soft rot bacilli found in affected parts).

Fig. 2. Small portion of epidermis from affected area, showing Rhizoctonia mycelium, low magnification.

Fig. 3. Small portion (Fig. 2) under higher magnification.

The disease affects young plants more particularly and kills them off early in the season. A disease of this character is common in Europe, particularly in Germany where it has been known for years. It is considered that it was introduced to the American continent from Europe on imported seed.

The disease was first described by Appel in Germany. He considered that it was bacterial and named the bacillus which he isolated from diseased specimens, *B. phytophthorus.*

The tops of plants affected with the disease lose their bright green color which fades away to a brownish or dirty yellowish green, presenting a withered and drooping appearance. On examining the lower stems of such plants the brown or black discoloration will be noticed. In many cases such discolored tissue will be soft rotting and an examination of the seed tuber usually shows it to have rotted away with a soft, slimy wet rot, often nothing but the skin being left. The soil underneath such a rotted seed tuber appears as though it had been wet puddled, due to the rapid extraction of water from the seed tuber during the rotting process. A microscopic examination of this soft rotting tissue, both in the seed tubers and the stems, shows large numbers of bacteria, usually several species being found in the older rotted parts.

In other cases of black leg where the stem of the plant is badly discolored, the soft rot may not be in evidence. A microscopic examination of the discolored epidermis shows no bacteria, but strands of fungus mycelium, most of which presents the typical appearance of the sterile fungus, *Rhizoctonia,* a species of fungus which is responsible for the root rot or canker of many vegetables. In some cases potato plants so affected appear later to get the better of the disease. That is, they do not die down or rot off; or, if some stems on the hill which are the worst affected die down, other stems not so badly affected or not affected at all develop apparently all right. However, later in the season when the crops are harvested, hills which have very vigorous tops, heavy foliage, and thick stems, may have also aerial tubers, that is, tubers as very irregular swellings on the stems above ground and usually a large cluster of very small malformed tubers crowded together at the surface of the soil. Examination of the underground stems of such plants usually shows discolored brown shrunken areas which evidently have been affected by the *Rhizoctonia.* The theory which has been advanced regarding the formation of such heavy top growth and the production of aerial tubers on the stems of the plant, with large clusters of small malformed tubers at the crown, is that the growth of the fungus on the stems of the plant interferes with the transmission of the reserve food substance manufactured in the foliage which, under normal conditions, is returned to the roots where it forms the tubers. The injury to the underground stems caused by the *Rhizoctonia* prevents the passage of this reserve food material to the usual parts of the root system and forces its deposition in abnormal places, either at the surface or above the surface of the soil in the shape of malformed tubers, which are usually small and numerous.

In many cases of the bacterial soft rotting type of black leg, the writer has found on the epidermis of the discolored stem, interlacing strands of *Rhizoctonia* mycelium. It is possible that this fungus is the primary cause of most cases of this disease and that the bacterial soft rotting of the affected tissue in such cases is secondary owing to an invasion of the weakened epidermis by the decay bacteria common in the soil.

The disease is most common in wet, backward seasons when the resistance power of the young growing plant is low.

PLATE VII.

***Bacterial Wilt of Cruciferae* (*Black Rot of Cabbage*).**

Figs. 1 and 2. Views in a cabbage plantation, showing numerous cases of the disease in all stages of development.

The disease of both types is carried over both in the soil and on or in the seed tubers.

The *Rhizoctonia* may be present on the surface of sound seed tubers as black or dark brown rough spots, raised above the surface, varying in size from a pin head to masses half an inch in diameter very irregular in shape. These are the resting stages of the fungus called sclerotia. When a tuber so affected is planted, these sclerotia germinate at the same time that the eyes and young roots of the potato develop. The mycelium from the germinating sclerotia spreads all around and comes in contact with the young growth of the potato, and if the young plant is not sufficiently resistant it falls a victim to the disease. The part attacked turns brown and shrinks, and the symptoms previously described develop.

The dark sclerotia masses on the seed tuber may be made much more distinct by dipping the potato in water; this will make them quite black in color. Potatoes with these sclerotia black spots on them should not be planted, and all seed tubers should be carefully looked over for them before planting. Also any tubers which show brown discolorations under the skin or brown areas in the flesh when they are cut should not be used, as the bacteria which cause the soft rotting type may be present in such discolored tissue.

BACTERIAL WILT OF CRUCIFERÆ.

(Black Rot of Cabbage, Turnip, Rutabaga, Etc.)

Causal organism—*Ps. campestris.*

This wilt, commonly known as Black Rot of Cabbage and sometimes as Brown Rot, is a very bad disease and causes much loss to the kitchen gardener. It is found attacking many cruciferous plants including cabbage, cauliflower, collards, Kohl rabi, kale, brussels sprouts, broccoli, rutabagas, turnips, wild radish, and mustard, the latter, unfortunately, only to a very slight extent.

It is widely distributed, occurring throughout Canada, United States, Great Britain, Holland, Germany, Denmark, Austria, France, Switzerland and other countries.

The specific cause of the disease was first ascertained by Pammela of Ames College, Iowa, in 1895 when on investigating a bad outbreak of a black rot of rutabagas he isolated a germ which he named *B. campestris,* grew it on various culture media, and, by inoculating healthy plants with the cultures so obtained, produced in them the disease and from these plants reisolated the germ. (Bulletin 27, Iowa College Experiment Station, 1895.)

Erwin Smith in 1896 (see Centralblatt für Bakteriologie, II Abte., Vol. 3, 1897) on investigating a brown rot of turnips and a black rot of cabbages, infected material of which was forwarded to his laboratory, isolated a germ which proved to be identical with that isolated by Pammela the year before from rutabagas. He conducted numerous inoculation experiments and established the germ as being the specific cause of the wilt of many cruciferous plants which is so common in moist weather, and which causes heavy losses to market gardeners.

PLATE VIII.

Fig. 1. Cabbage leaves affected with the bacterial wilt or black rot. The lighter-shaded areas around the outer edge of the leaves are the diseased parts showing natural inoculation through the water pores on the edge of the leaves.

Fig. 2. The lighter shade part of the leaf near the base indicates the diseases, and the blackened vascular bundles of the stem, where it is cut, indicates that the disease entered this leaf from the main stalk of the cabbage.

Fig. 3. Cabbage stalk and stunted head; the blackened vascular bundles indicate that the disease was general throughout the plant. The leaf of Fig. 2 was taken from this plant.

Appearance of the Disease.

In the growing cabbage plant the disease manifests itself as a yellowing or browning of the leaves. This yellowing occurs in irregular areas sharply defined, which gradually enlarge until the whole leaf becomes browned, wilted and shrivelled.

If the plant be attacked by the disease when young it will not develop normally, but will be dwarfed, and will present a pale, sickly appearance and often no head will be produced in the case of a cabbage, and no bottom produced in the case of a turnip or rutabaga. (See illustration.)

The browning and wilting of the leaves is due to the supply of sap being cut off in the veins and midribs that are situated near or within the brown areas.

If the midrib of a diseased leaf or the veins leading from a diseased part of a leaf be cut it will be noticed that the vascular bundles or fibres are black or dark brown instead of yellow or white. This discoloration is due to the presence and action of immense numbers of the disease-producing bacteria within the veins or fibro-vascular bundles. Here they feed on the sap, multiply rapidly and choke up the passages so that the supply of sap is cut off from the surrounding tissue, thus causing it to yellow, wilt and die.

If the whole head of cabbage be yellowish, sickly, and wilted, or if several leaves of a cabbage present such an appearance, a section of the stalk, either cross or longitudinal, will almost invariably reveal the disease in the blackened vascular bundles forming the vascular ring, the woody portion of the stem. In such a case the germs will have spread almost throughout the entire vascular system of the plant, passing down the veins of one leaf into the stem where they would pass both up and down the veins of the stem to veins of other leaves until the whole plant became affected and worthless. (See illustration.)

Means of Infection. Infection is most common at the water pores around the margin of the leaf. In the early morning, especially in moist weather, dew-drop-like beads of water may be noticed around the leaf margins of growing cabbages. This is usually water of transpiration given off by the plant through the water pores. If the atmosphere were dry this water would not be found there as it would evaporate as soon as it came to the surface of the plant. But when the atmosphere is moist this evaporation does not take place and so the water extruded from the pores forms little beads.

Should the disease germs by any chance get into these drops of water it is very easy for them to enter the vascular system of the plant through the open pores. Thousands of cases where such has been the means of entrance of the germs into a plant have been observed.

The question remains: How do the germs get into the drop of water? This may occur in several ways. Slugs and caterpillars crawling around after feeding on or crawling over a diseased plant may carry and deposit the germs wherever they crawl on the healthy plants. The cultivator in passing along the rows may brush against and wound a diseased plant and some of the germs thus get onto the cultivator and so be carried along and brushed off on healthy plants. In transplanting, the hands of the workman may become contaminated from handling a diseased plant, and plants subsequently handled have the germs deposited on them from the hands of the workman. Even should the plant be dry at the time it is so contaminated, the germs may remain alive on the plant for days until the right conditions occur, that is, sufficient moisture be present in the atmosphere and in the soil to allow of the formation of water drops at the water pores when infection would take place.

PLATE IX.

Bacterial Wilt of Cucurbits.

Fig. 1. Bacterial wilt of cucumber.

Fig. 2. Bacterial wilt of cucumber.

Fig. 3. Bacterial wilt of squash.

Fig. 4. Stained microscope preparation from the viscous slimy exudate of a vascular bundle of a wilting cucumber plant, showing the bacteria (*B. tracheiphilus*), (x 1000 di.).

Again, biting insects, caterpillars, slugs, and other forms of animal life which feed on growing cabbages, may, after feeding on a diseased plant, inoculate directly a healthy plant by biting through one of the small leaf veins and depositing there some of the germs adhering to their mouth parts after their visit to the diseased plant. Such means of inoculation have been observed again and again. Caterpillars and slugs feeding on diseased leaves have been transferred by hand to healthy plants and in a large percentage of cases the disease has subsequently developed in the healthy plants at the point where the caterpillar was placed.

Infection through contaminated seed may occur. By a series of experiments conducted at the New York Experiment Station, Geneva, it has been proven that the germ can live on dry seed for longer than nine months. Such contaminated seed when germinating is liable to infect the young plant, and cases of such infection may occur in seed beds.

Again, seed beds are often badly contaminated with the germ by spreading on them material from the manure pile or compost heap where diseased plants have been deposited to rot. And while it is very doubtful that the germ enters the plant through the root hairs, any injury to the root, or leaves that are near the ground, may result in the inoculation of the plant with the disease. Caterpillars and slugs crawling over such soil would be very liable to inoculate the plants growing there by crawling over and feeding on them.

Control of the Disease.

The best way to keep the disease under control is to prevent its development.

Disinfecting the Seed. It was proven at the Geneva station that germs on the seed may be killed without any injury to the seed by soaking it for fifteen minutes either in a corrosive sublimate solution or in formalin.

If corrosive sublimate is used, the strength of the solution should be one part corrosive sublimate to one thousand parts of water. The most convenient method of preparing this solution is to use the corrosive sublimate tablets sold by druggists for making disinfecting solutions. One tablet, costing one cent, is sufficient to make a pint of solution which is about the quantity required to treat one pound of seed. The seed should be soaked in this solution fifteen minutes and then spread out to dry.

If formalin is used the strength of the solution should be one part formalin (40 per cent. formaldehyde) to 240 parts of water and the seed soaked for fifteen minutes.

A convenient method of treating the seed is to place it in a small bag made of any loose cloth readily penetrated by water and suspend the bag in the disinfecting solution for the required length of time. The seed should be dried without delay in the shade.

Handling Diseased Plants. Should the disease be noticed among seedlings in the seed bed, the diseased plants should be removed and burned. If they are not burned the germs within them are liable in many ways to get transferred to the healthy stock, and so the disease be spread instead of being checked.

Seedlings that show signs of the disease should not be planted out. It is not usually of much service simply to break a diseased leaf from what appears to be an otherwise healthy plant. If the disease is confined to the marginal areas of the leaf entirely, then breaking off the leaf would prevent the rest of the plant from developing the disease. But, should the vascular bundles in the midrib of the

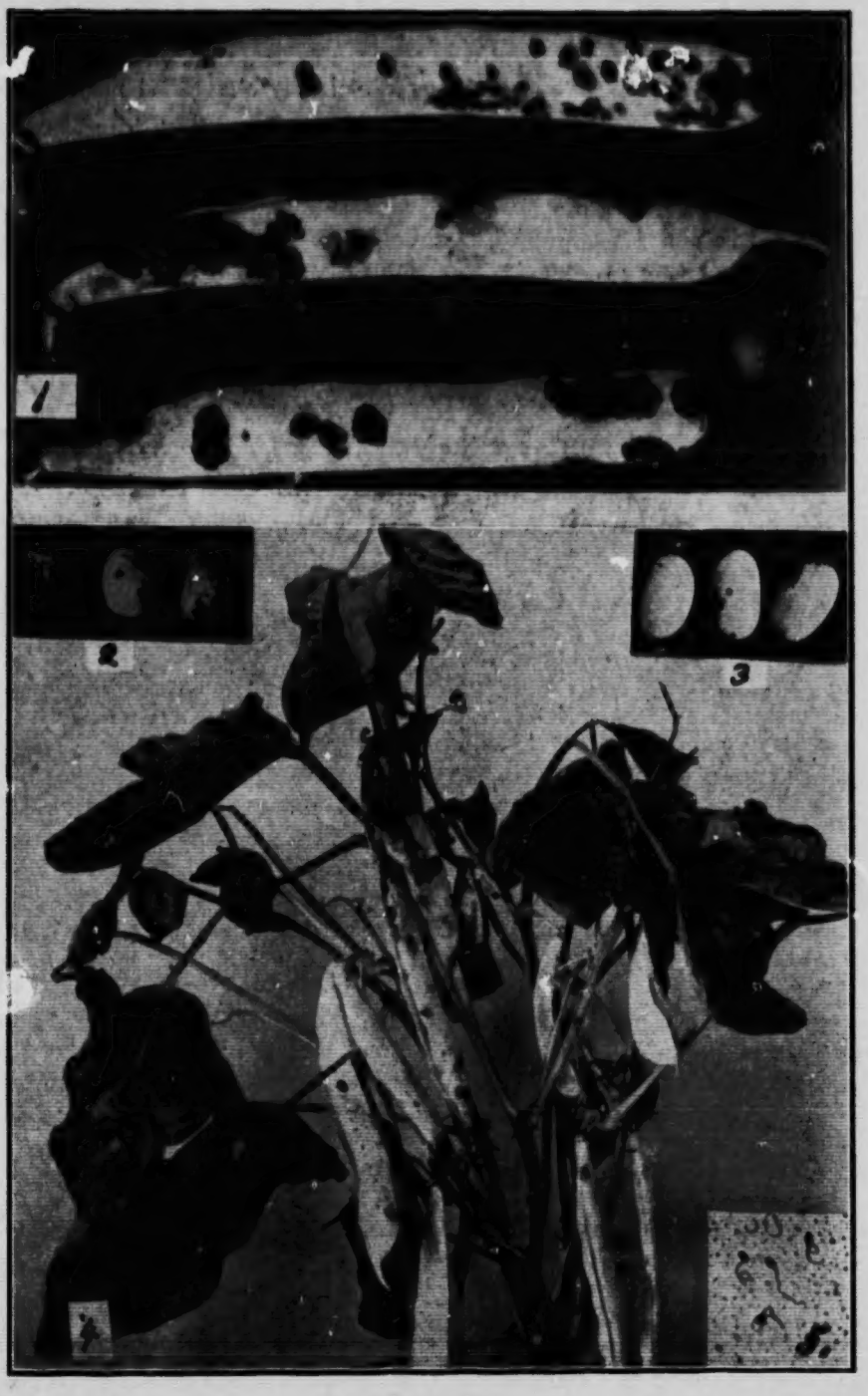

PLATE X.

Bacteriosis of Beans.

Fig. 1. Diseased pods.
Fig. 2. Diseased beans from diseased pods.
Fig. 3. Healthy beans.
Fig. 4. Bean plant badly affected with bacteriosis in foliage and pods.
Fig. 5. *Ps. phaseoli*, the cause of the disease.

leaf at the point of its contact with the plant stalk be discolored brown or black, we may take it for granted that the germs are already established in the vascular bundles of the stalk. So after breaking off a diseased leaf one should look to see if any discoloration of the vascular bundles exists, and should there be any, the whole plant should be destroyed.

If an entire bed, or a considerable portion of a bed be badly attacked, all the plants should be pulled and burnt and the broken leaves, etc., raked up and burnt also. Cabbage or turnips should not be planted again on such ground for one or two years.

Insects and caterpillars, slugs, etc., should be kept in check as they are noted carriers of the disease germ by feeding on diseased plants and then going to healthy plants.

BACTERIAL WILT OF CUCURBITS.

Causal Organism, *Bacillus. tracheiphilus.*

This wilt often causes serious losses to the growers of cucumbers, squashes, melons, and other cucurbits. Whole plantations of these plants are sometimes completely destroyed, and the disease will pass rapidly through a house of cucumbers.

A diseased plant loses its bright green color and turns to a dull, dirty yellowish green. The leaves and stems become flaccid and droop, hang down limp and lifeless, having lost all turgidity. The fruit when affected becomes soft and appears somewhat water-soaked, and if squeezed will readily yield to pressure, and often under such treatment the skin will rupture and a slimy clear liquid will ooze out. If this liquid be touched with the finger or any instrument, it will be found to be viscid, slimy or gummy, and will string out in long strands. If a diseased stem be broken or cut, similar conditions will be found to exist, i.e., the plant juice will be viscid, slimy and will string out in long strands when the cut surface is scraped with a knife or rubbed with the finger.

This sliminess or viscidity is the most characteristic feature of the disease, for a plant may wilt for lack of moisture and present an appearance something like a diseased plant. But if such a plant be cut and its juice expressed, this juice will prove to be quite watery and will not draw out in threads.

A microscopic analysis of the slimy juice from a diseased plant will show millions of bacteria within the smallest drop that can be obtained. While a similar preparation made from the juice of a healthy plant or a plant that has wilted merely from the lack of moisture will not show a single germ.

If a little of this slimy juice from a diseased plant be transferred on the point of a needle to the inner tissue of a healthy plant by puncturing the healthy plant with the contaminated needle, in a day or two the plant will wilt, the bacteria inserted on the point of the needle having multiplied so rapidly and spread through the vascular system of the plant.

Pure cultures of the germ on artificial media are rather difficult to obtain as the germ will not grow readily on the ordinary media. However, pure cultures have been obtained on special media, and these inoculated into healthy plants have rapidly produced the disease.

In the stem and leaf the disease germ is found mostly in the vascular bundles, in the plant juice of which it lives and rapidly multiplies, spreading up and

down and plugging the sap channels. Eventually the walls of the vascular bundles are broken down and the organism gets into the surrounding tissue to a limited extent.

The flesh of diseased fruit is transparent and water-soaked in appearance.

The plant juice in all affected parts becomes slimy or viscid and strings out in long strands.

Methods of Spreading.

1. The disease is spread from plant to plant mostly by biting and sucking insects, particularly the striped cucumber beetle and the squash bug. These insects after feeding on a diseased plant have their mouth parts covered with the germs of the disease and on subsequently feeding on healthy plants they inoculate the healthy tissue with the disease.

2. The gardener in removing and destroying the diseased plants cannot help but get his hands and the tools used badly contaminated with the disease germs even when exercising the greatest care, and so if he does not take the precaution to disinfect his hands and the tools used before handling any healthy plants, he is very likely to inoculate them with the germs of the disease.

Methods of Control.

All diseased plants should be carefully removed and burned immediately. If they are allowed to lie around insects will swarm about them, get themselves contaminated with the germs and thus spread the disease wherever they go.

Hands and tools used in removing and destroying diseased plants should be thoroughly disinfected by washing them in five per cent. carbolic acid, or in corrosive sublimate of a strength one to one thousand, or some other good disinfectant.

Biting and sucking insects, especially the striped cucumber beetle and squash bug, should be kept under control by spraying and hand picking.

BEAN BLIGHT.

Bacteriosis of Beans.

Causal organism, *Ps. phaseoli* (Smith).

Whilst there has been no record of heavy losses from this disease in Ontario, we get every year bean plants suffering from the disease forwarded to us. Letters accompanying these plants often state that considerable damage was done to the fields from which the plants were taken, many plants being attacked in the same way. Scarcely a season passes but what more or less of this disease is present in the beans of the College garden and in the bean plots in the experimental grounds. In the United States where wax beans and lima beans are grown extensively, heavy losses are caused by the disease, and it is getting more general in Ontario.

Beach of the Geneva Station established the bacterial character of the disease on lima and wax beans in 1892, and Halstead of the New Jersey Station in the same year arrived at similar conclusions after making a series of experiments. Erwin Smith in 1897 first described the causal organism, *Ps. phaseoli*. Work dealing with this disease has also been done in this laboratory.

The disease may be found on the foliage, the stems, the pods and the beans within the pods. At first the disease on the pods appears as small, water-soaked areas. These areas gradually enlarge and usually are outlined by a reddish-brown border. As the disease progresses and the areas continue to enlarge, the whole of the affected area becomes a light brown, and does not develop the black or pink color or the sunken spots produced by anthracnose. The foliage becomes spotted and yellowed in large areas of the leaf surface, soon withers and falls away.

Method of Infection.

Leaves. The disease usually begins at the margin of the leaf, or where the leaf has been torn by insects, wind or hail. Here the germs find entrance into the plant tissues through the wound. A yellow spot is formed and the green color destroyed. The spot increases in size rather slowly, and the diseased tissue becomes brown and papery, turning dry and brittle in the sun and soft in the rain, and then is often torn away leaving ragged margins and holes in the leaf. The whole leaf may die and fall to the ground or remain withered on the stem.

Stems and Pods. The disease usually enters the stem by way of the leaf stalk, and advances in the stem to other leaves and to young pods. In severe cases the pod may wilt and die, and on opening it the half-grown seeds will be found shrivelled and discolored by irregular brownish areas outlined by the characteristic reddish-brown margin. The beans may be apparently sound or only slightly discolored or they may be much discolored. The whole plant does not usually die outright, but lingers through the season. Separate infections may occur at any place on pod or stem.

Seed Beans. In germination tests of diseased beans less than half the number sown germinated. The remainder rotted. Those that germinated never produced healthy plants but plants that were weak and soon wilted. Healthy seed sown under the same conditions germinated a ninety-eight per cent., and produced vigorous healthy plants.

The germs live over winter in the bean tissue and infect the plant on germination.

In appearance the disease is somewhat similar to bean anthracnose or "pod spot" caused by the fungus *Collitotrichium lindimuthianum*, but this latter may be distinguished by its making rather deep pits in the affected areas which are pinkish and produce spore-bearing pimples.

Causal Organism, *Ps. Phaseoli.*

In morphology and cultural characteristics *Ps. phaseoli* is practically identical with *Ps. campestris* which causes wilt or black rot of cabbages. But while it is pathogenic for beans, peas and lupines, it is not pathogenic for cabbage or cauliflower. And while *Ps. campestris* is pathogenic for most crucifers, it is not pathogenic for the legumes.

The organism has been isolated by Delacroix from French grown plants at Paris.

Eradication and Control.

Do not sow seed from diseased plants. Remove infected plants and burn them.